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# Pacific Northwest National Laboratory

Operated by Battelle for the  
U.S. Department of Energy

## GridLAB-D Technical Support Document: Commercial Module Version 1.0

DP Chassin

May 2008

Prepared for the U.S. Department of Energy  
under Contract DE-AC05-76RL01830



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Richland, Washington 99352



## **Acronyms and Abbreviations**

ODE	ordinary differential equation
ETP	equivalent thermal parameters
UA	thermal conductance (surface area x thermal conductivity)

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# 1.0 Introduction

The Commercial Module implements commercial building models. Version 1.0 of this module only supports single-zone office buildings. Support for additional commercial buildings types is planned, including multi-zone office, schools, stores, and refrigerated warehouses.

## 2.0 Single-Zone Office Building

The Commercial Module uses a simple Equivalent Thermal Parameters (ETP) model (Taylor and Pratt 1988) with first-order ordinary differential equations (ODEs):

$$\dot{T}_i^* = \frac{1}{c_a} [T_m h_m - T_i(UA - h_m) + \Sigma Q_{in} + T_o UA] \tag{2.1}$$

$$\dot{T}_m^* = \frac{h_m}{c_m} [T_i - T_m] \tag{2.2}$$

where

$T_i$  = the temperature of the air inside the building

$$T_i^* = \frac{dT_i}{dt}$$

$T_m$  = the temperature of the mass inside the building (for example, furniture, inside walls)

$$T_m^* = \frac{dT_m}{dt}$$

$T_o$  = the ambient temperature outside air

$UA$  = the UA of the building envelope

$h_m$  = the UA of the mass of the furniture, inside walls, etc.

$c_m$  = the heat capacity of the mass of the furniture inside the walls, etc.

$c_a$  = the heat capacity of the air inside the building

$Q_{in}$  = the heat rate from internal heat gains of the building (for example, plugs, lights, people)

$Q_{ht}$  = the heat rate from heating, ventilating, and air conditioning unit

$Q_s$  = the heat rate from the sun (solar heating through windows, etc.)

The general first order ODEs ( $C_1$ - $C_5$  defined by inspection above) is

$$\dot{T}_i^* = T_o C_1 + T_m C_2 + C_3 T_m^* = T_o C_1 + T_m C_2 \tag{2.3}$$

The general form of the second-order ODE is

$$p_1 \dot{T}_i^* + p_2 \ddot{T}_i^* + p_3 T_i^* \tag{2.4}$$

The solutions to second-order ODE for indoor and mass temperatures are

$$T_i(t) = K_1 e^{r_1 t} + K_2 e^{r_2 t} + \frac{p_3}{p_1} \tag{2.5}$$

$$T_m(t) = \frac{T_i(t) - C_1 T_o - C_2 T_m(t)}{C_3} \tag{2.6}$$

where:

$$r_1, r_2 = \text{roots}(p_1, p_2, p_3)$$

$$K_1 = \frac{(r_2 T_o - r_1 \frac{p_3}{p_1} - T_o)}{r_2 - r_1}$$

$$K_2 = \frac{T_o - r_2 \frac{p_3}{p_1}}{r_1}$$

$$P_1 = \frac{1}{C_1}$$

$$P_2 = -\frac{C_2}{C_1} - \frac{C_2}{C_2}$$

$$P_3 = C_3 \frac{C_1}{C_2} - C_4$$

$$P_4 = -C_5 \frac{C_1}{C_2}$$

$t$  = the elapsed time

$T(t)$  = the temperature of the air inside the building at time  $t$

$T_o = T(t = 0)$ , for example, the initial temperature of the air inside the building

$T_o' = T'(t = 0)$ , for example, the initial temperature gradient of the air inside the building

### 3.0 References

Taylor, ZT and RG Pratt. 1988 "The effects of model simplifications on equivalent thermal parameters calculated from hourly building performance data." In *Proc. 1988 ACEEE Summer Study on Energy Efficiency in Buildings*, pp. 10.268-10.285.